A Machine Learning Assisted Development of a Model for the Populations of Convective and Stratiform Clouds

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Overview

Informed by radar observations and companion cloud-permitting model simulations, we make use of machine learning to develop a model for the evolution of populations of convective cells and their associated stratiform area. We focus on characterizing the interactions between convective and stratiform clouds. Such coupling is an important parameterization issue (e.g., the convective source term in PC2) and the model may also be valuable to inform nowcasting projections.

Data

We use 15 seasons (~157,032 frames) of C-POL radar reflectivity data from Darwin, Australia covering (150km)² every 10 min. The Steiner et al. (1995) algorithm distinguishes convective cells from the stratiform area.

Model and learning method

The stratiform area s and convective cell size distribution c evolve according to

\[ \frac{ds}{dt} = f_s(c) - \frac{s}{\tau_s} \]

\[ \frac{dc}{dt} = f_c(s, c) \]

where \( \tau_s = \sum \tau_c \) is the total convective area. Machine learning is used to obtain \( f_s, f_c, \) and \( \tau_c \) with the C-Pol data providing snapshots of \( c, s, \Delta c \) and \( \Delta s \).

A look at \( f_s(c) \)

The stratiform growth rate increases with convective area fraction and is larger for many small cells rather than a few large cells. Its behaviour can be understood as resulting from hydrometeors being detrained through the perimeters of the convective cells.

A look at \( f_c(s, c) \)

We can assess the effects of stratiform cloud on the convective cell population by looking at the change in population due to disabling the \( s \) dependence of \( f_c(s, c) \). We set it instead to \( f_c(0, c) \). Stratiform feedback favours smaller cells for a given convective area.

Tests with imposed forcings

We now integrate the derived model with imposed forcings. First we take a constant mean forcing but with a random element also applied in order to demonstrate how the character of the interactions embodied in \( f_s \) and \( f_c \) affects the maintenance and nature of an equilibrium cloud distribution. We find that stratiform feedback does not affect the total convective area but it does change the distribution as above. It also increases the stratiform area and is important for convective variability, as it acts to dampen large fluctuations in the cell size distribution.

Conclusions

- Machine learning can be used to build a model showing the interactions between convective and stratiform cloud.
- A large number of small convective cells is favourable for stratiform area growth
- In turn, stratiform cloud feedback favours smaller convective cells and acts to dampen convective variability.
- The model has been devised with a view towards implementation as a parameterization, and some tests are underway by ZH in WRF.

References


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